Air Force Materiel Command

Developing, Fielding, and Sustaining America's Aerospace Force

U.S. AIR FORCE

The Macro Dynamics of Weapon System Acquisition: Shaping Early Decisions to Get Better Outcomes

Dr. Ed Kraft

Chief Technologist

Arnold Engineering Development Center

May 17, 2012

Integrity - Service - Excellence

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
17 MAY 2012		**00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Macro Dynamics of Weapon System Acquisition: Shaping Early Decisions to Get Better Outcomes	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Arnold Engineering Development Center,100 Kindel Drive,Arnold AFB,TN,37389**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the 9th Annual Acquisition Research Symposium, May 16 - 17, 2012, Monterey, CA.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**15**	

Challenges

- Defense acquisition is already broken
  - Systems Engineering – event driven vs effects based
  - Reduced Capacity – “procurement holidays” increase cycle time and costs
  - Complexity – A&D community self inflicted wound
  - Requirements – not necessarily connected to mission, physical reality, affordability, and ability to deliver on time
- Reduced budgets are a fact of life
  - Fewer acquisition new starts
  - Reduced infrastructure, reduced capacity
  - Not if or when, but how much
- Over the next decade the US could loose technological superiority, economic competitiveness in key areas
- We have to get past policies to systemic root causes to overcome pending reductions and increase the output of the US Aerospace and Defense industry

Key Systems Engineering Leverage Points
Marked by Events – Mired by Lack of Effectiveness

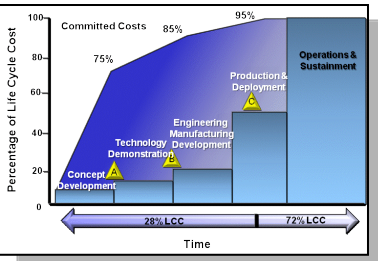
AFMC

GAP | MDD | A | B | C

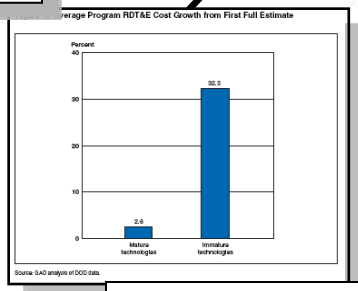
Capability Based Planning (CBP)	Materiel Solution Analysis (MSA)	Technology Development (TD)	Engineering and Manufacturing Development (EMD)	Production and Deployment (P&D)	O&S

Root Cause

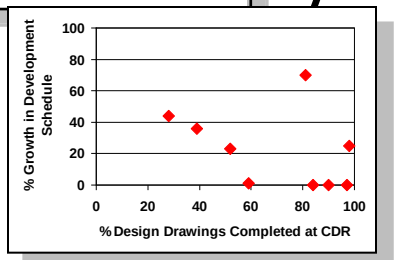
Discovery



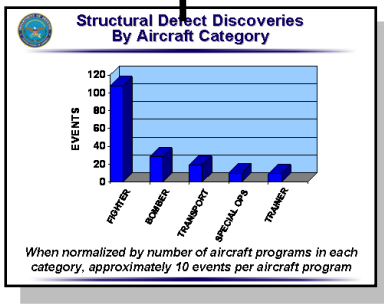
1. 75% LCC fixed @ MS A



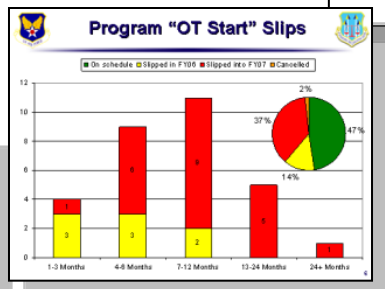
2. Technology Maturity @ MS B



3. Design Closure @ CDR

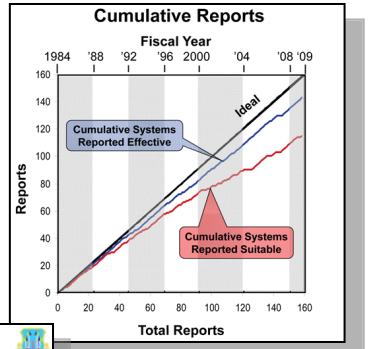


4. Late Defects

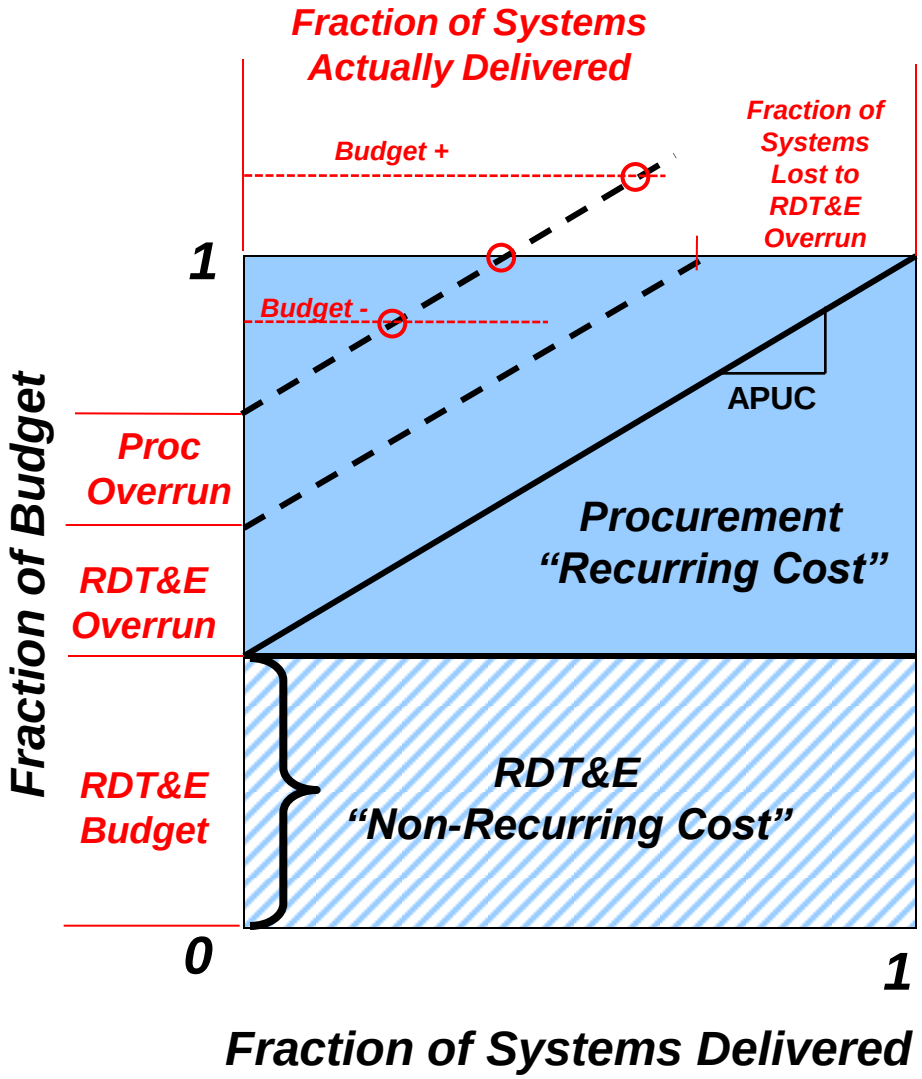


5. IOT&E Pause Test Rate

6. Suitability



Top Line Economic Model
Understanding Impact of Reduced Capacity



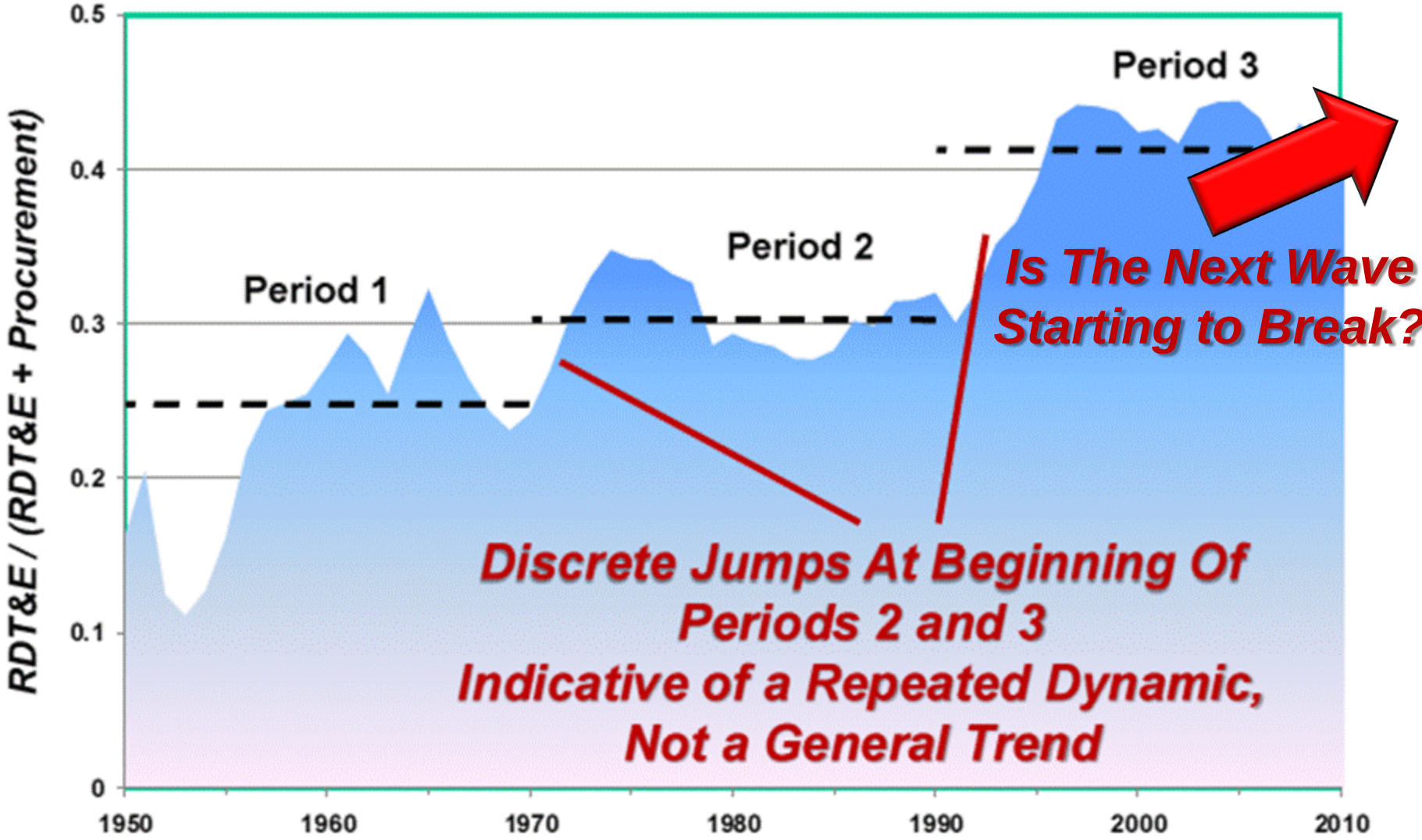
Final number of systems actually delivered driven by:

- **Overruns**
- **Congressional or DoD dictates**
- **Final Budget constraints**

$$\text{Fraction of Systems Actually Delivered} = 1 - \frac{\text{RDT\&E Overrun} + \text{Proc Overrun} \pm \text{Delta Budget}}{1 - \text{RDT\&E Budget}}$$

RDT&E Budget fraction amplifies the RDT&E and Procurement overruns plus Budget changes!

RDT&E Fraction of the DoD Acquisition Budget



Macro-Dynamics of Acquisition

Moving From Symptoms to Systemic Causes

AFMC

- Acquisition output impacted by RDT&E Fraction of acquisition costs

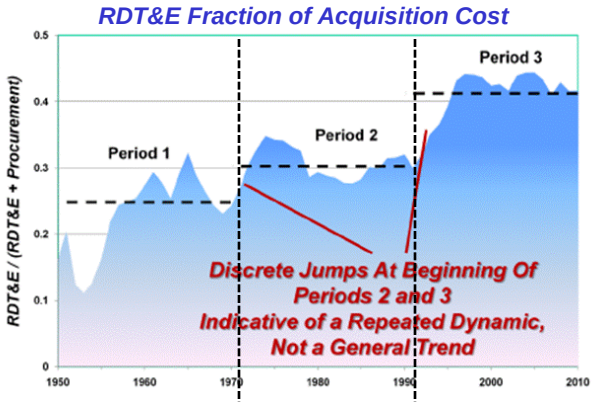
$$\text{Fraction of Systems Actually Delivered} = 1 - \frac{\text{RDT\&E Overrun} + \text{Proc Overrun} - \text{Delta Budget}}{1 - \text{RDT\&E Budget}}$$

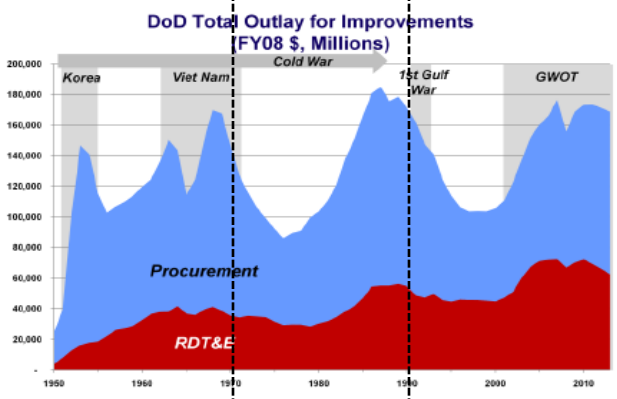
- Discrete jumps in RDT&E Fraction align with "Procurement Holidays" – not a general increase attributable to complexity

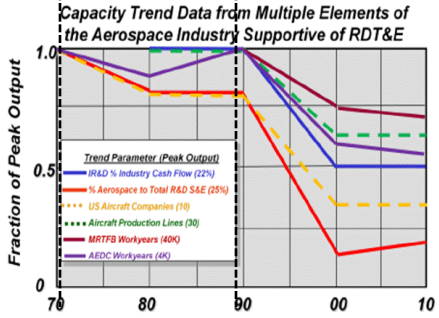
- Fundamental dynamic cycle –
  - At onset of each period, procurement decreases but RDT&E stays constant because of backlog
  - At end of each period, procurement increases and so does RDT&E because of new starts added to backlog

- Correlating causative factor –
  - Capability and capacity of system reduced at beginning of each cycle but not rebuilt during the ascending end of the cycle – bathtub effect, more RDT&E coming in but less going out

Acquisition system has passed a tipping point leading to pathological firefighting







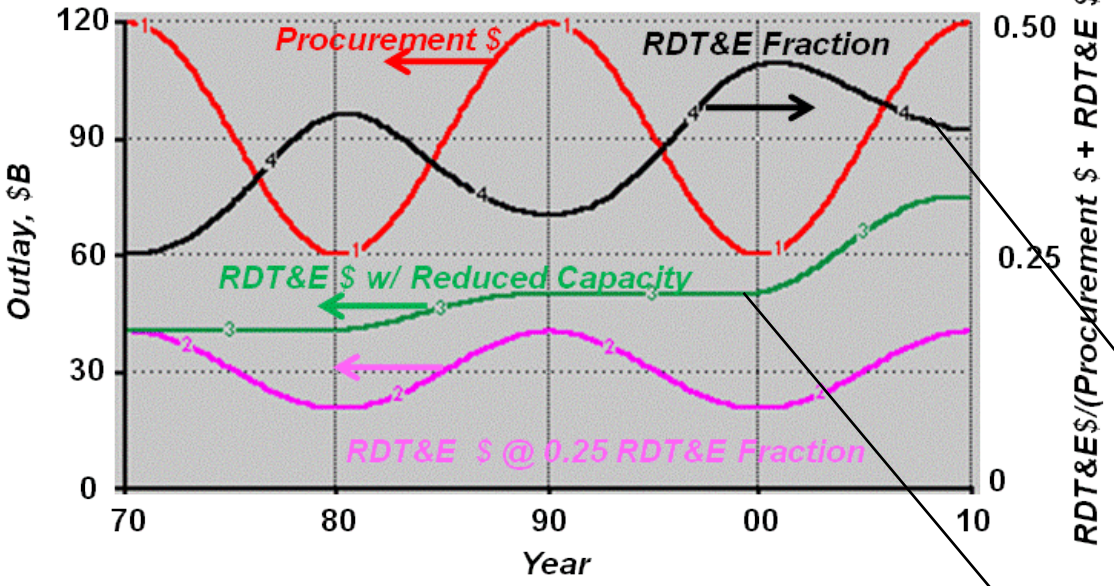
Doesn't Matter Which Way the Budget is Headed

- **Declining Acquisition Budget**
  - **Reduced capacity, capability, intellectual capital**
  - **Programs already in development continue with less capacity for development**
- **Increasing Acquisition Budget**
  - **Increase in new starts added to programs already in development**
  - **Capacity, capability, and intellectual capital not increased to meet new demand**

Both scenarios lead to a mismatch between capacity and demand leading to *pathological firefighting* for all programs

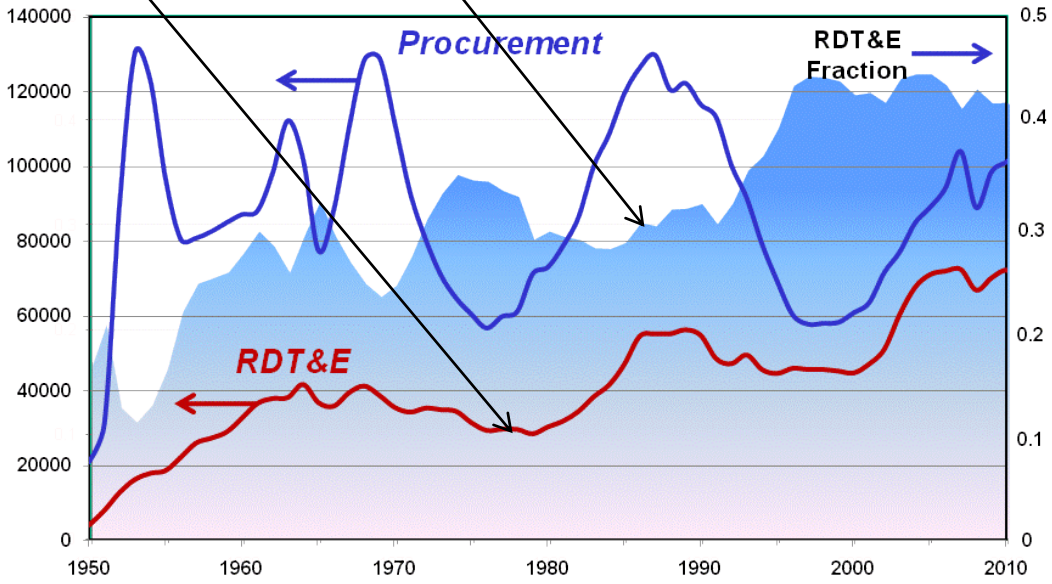
Simple Dynamic Model

Effect of Reduced RDT&E Capacity

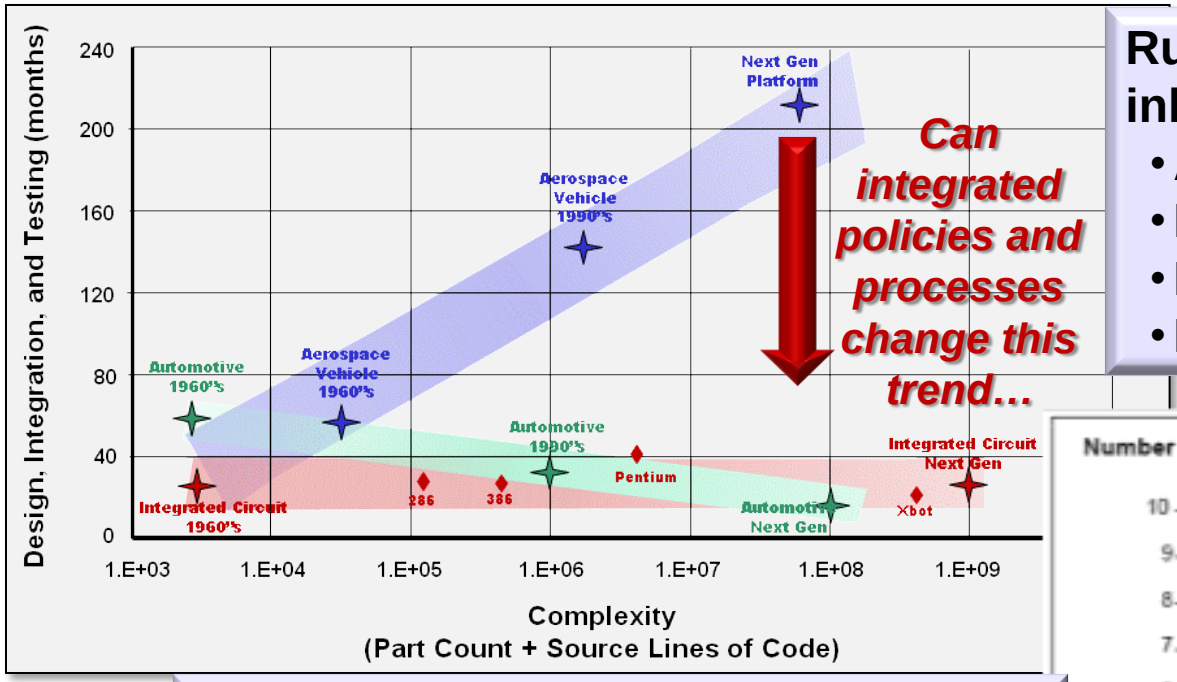


- Simple sinusoidal Proc $ with 20 yr period , $90B±$30B
- Baseline RDT&E $ expended at 0.25 Acq $
- With perfectly balanced, infinitely elastic capacity RDT&E $ would stay at 0.25 Acquisition $

- Reduced capacity consistent with previous chart
  - -15% in 70's,
  - constant in 80's @ 85%,
  - further reduced 25%in 90's
  - constant in 00's @ 60%
- Replicates major trends, Total RDT&E $ and RDT&E Fraction escalate after each cycle

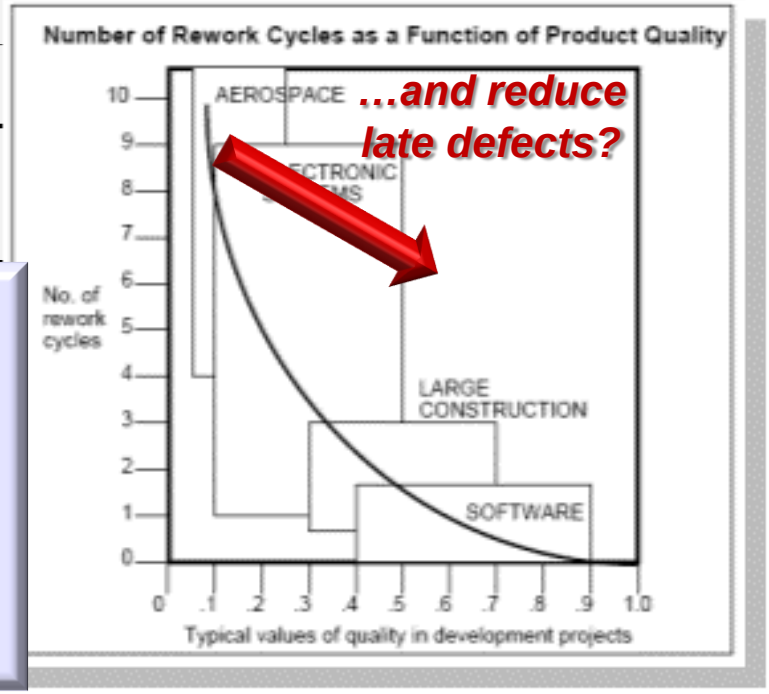


Complexity
A Self Inflicted Wound?



Runaway cycle time not inherent to added complexity

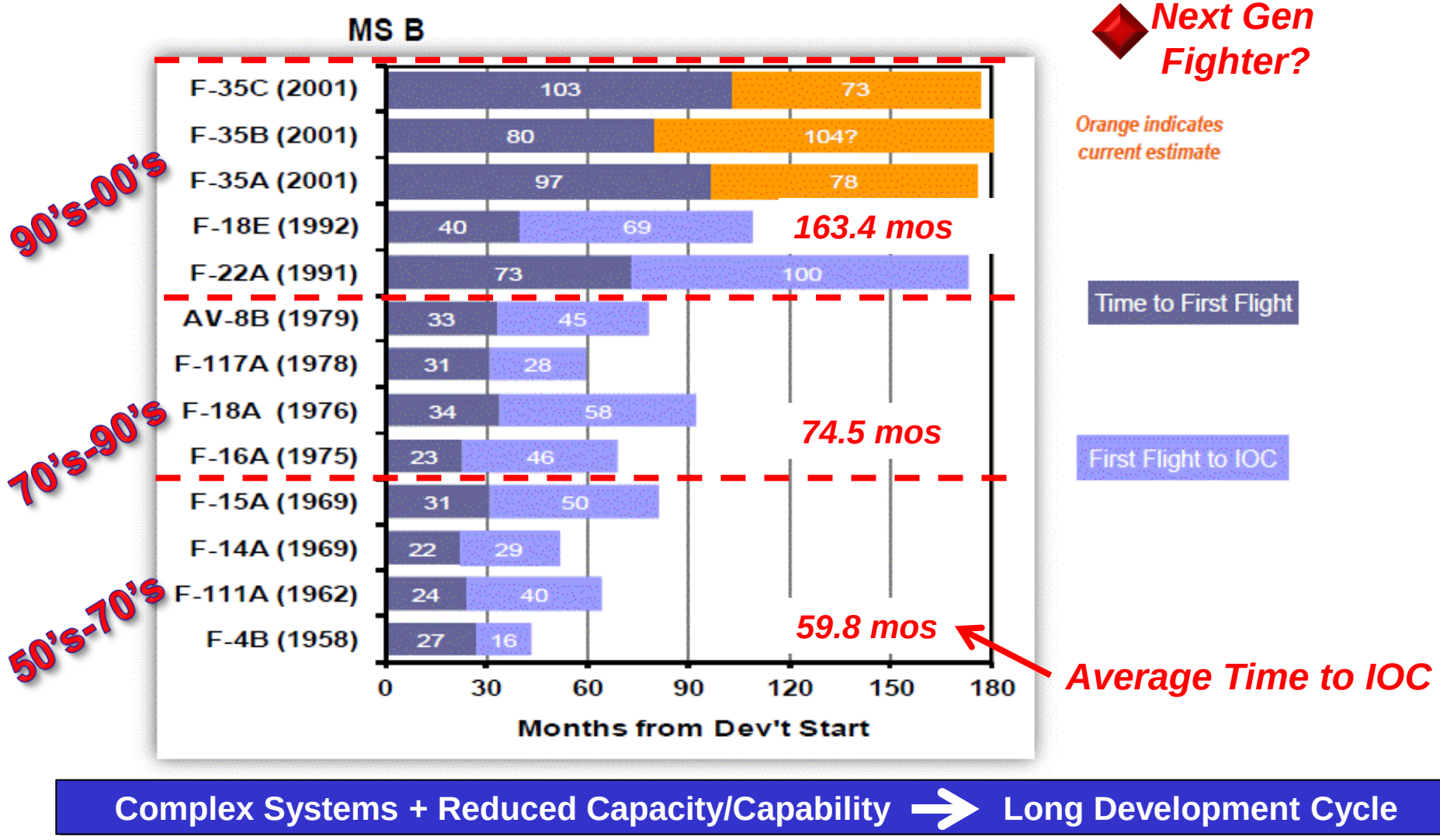
- Architecture choices
- Processes
- Process ownership
- Lack of Accountability



Aerospace industry rampant with late defects and rework

- Design tools and processes
- Lack of feedback to key design and SE processes
- Lack of quantified risk and uncertainty at key decision points

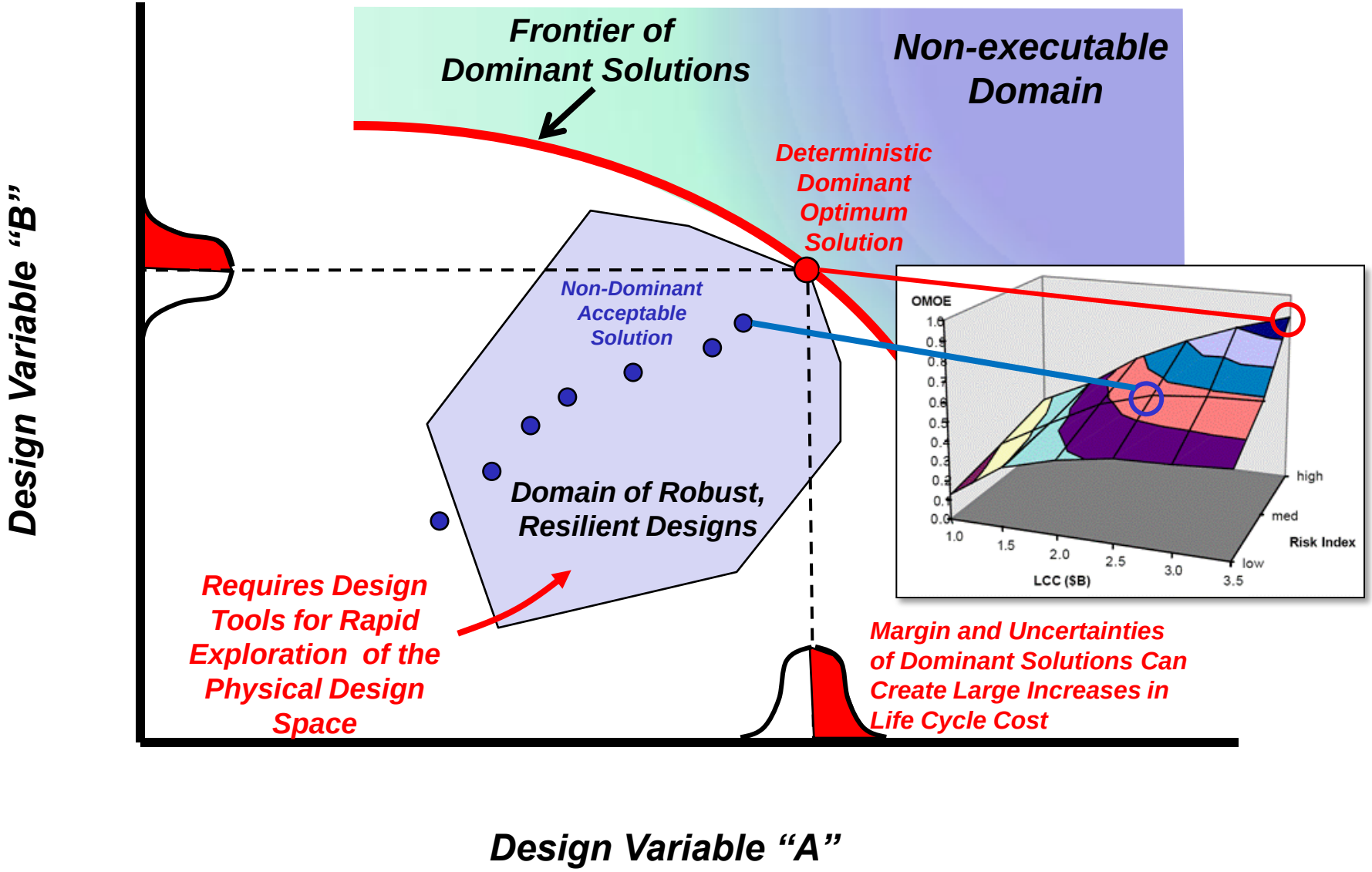
Impact of Reduced Capacity and Increased Complexity



Complex Systems + Reduced Capacity/Capability → Long Development Cycle

Requirements Setting

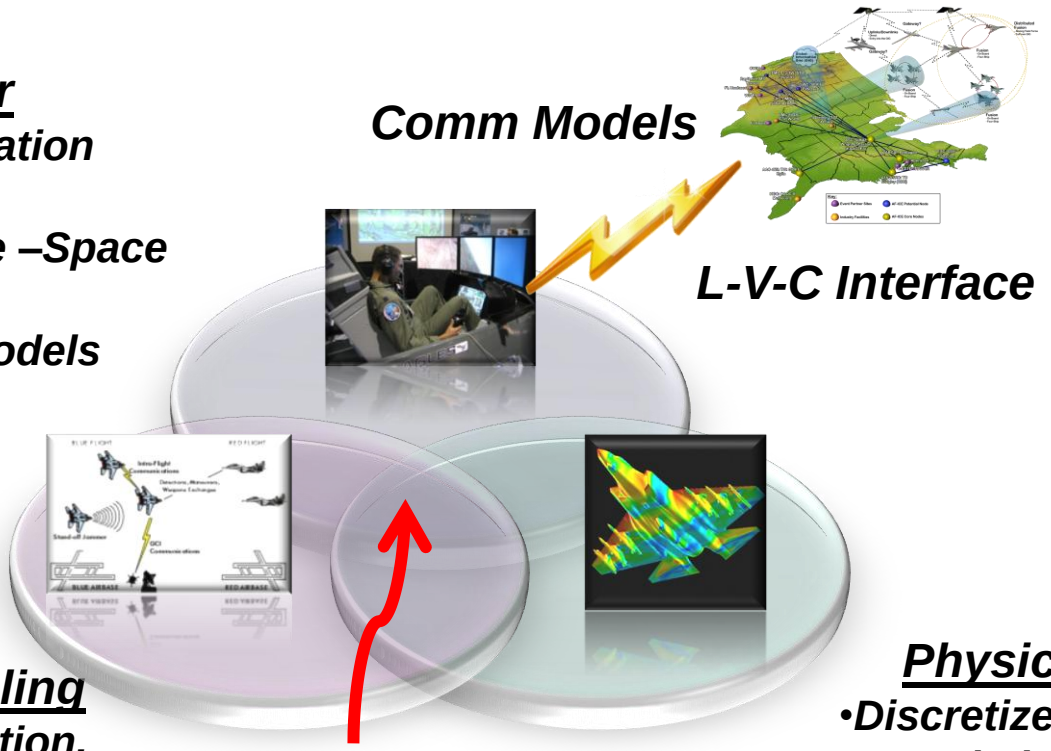
Robust, Resilient Design Vice Single Point Optimum Solution



Coupling Operability, Interoperability, and Physical Feasibility Analyses – a Game Changer

Simulator

- *Discrete Event Simulation*
- *Real Time*
- *High Resolution Time –Space Visualization*
- *Event Engineering Models*
- *Table Look Ups*



Operational Modeling

- *Discrete Event Simulation, Agent Based Modeling*
- *< Real Time*
- *Scenario Visualization*
- *Event Engineering Models*
- *Table Look Ups*

Physics Modeling

- *Discretized Physics*
- *> Real Time*
- *Phenomena Visualization*

Common Interface Built on Reducing Physics Models to Light Weight Algebraic Relations

Integrating M&S, RDT&E, and Statistical Engineering for Life Cycle Support

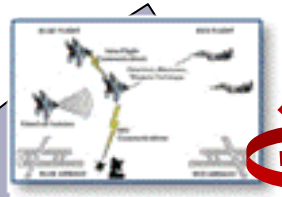
AFMC

GAP MDD A B C

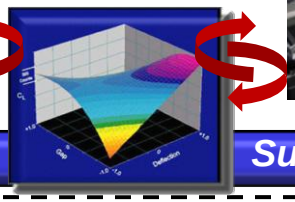
Capability Based Planning (CBP)	Materiel Solution Analysis (MSA)	Technology Development (TD)	Engineering and Manufacturing Development (EMD)	Production and Deployment (P&D)	O&S

Solutions • Non-Materiel • Materiel	Trade Space	Maturation	Allocation		Next Block

- Feasibility
- Operability
- Manufacturability
- Affordability
- Testability



- KPPs
- MOP/MOE

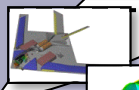


- SoS
- Interoperability
- Training

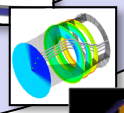
M&S

Sustained System Model Across LC

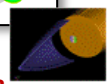
DaVinci



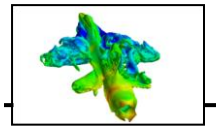
Firebolt



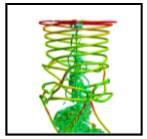
RF Antenna



Response Surface System Model



Kestrel



Helios

Quantified Margins and Uncertainties at Each Critical Decision Point

High-Fidelity Physics-Based Models

Rig, Component Tests

Ground Test

Flight Test

RDT&E

A Continuum of Tools Underpinned with Statistical Engineering to Quantify Margins and Risks at Key Decision Points

Early Decisions for Better Outcomes

Better Tools and Processes Applied Earlier

- **Systems Engineering – event driven vs effects based**
  - **Quantified margins/uncertainties at key decision points, particularly MS A/B**
  - **Accountability for risk management**
- **Reduced Capacity – "procurement holidays" increase cycle time**
  - **Increase effective capacity by reducing total workload and late defect discoveries through better design tools and technical process changes**
- **Complexity – aerospace/defense community self inflicted wound**
  - **Platform based engineering, common architectures for most software systems vice clean sheet approach**
  - **Increases in complexity have to "buy" their way onto the system during the requirements setting phase, including impact on acquisition cycle time**
- **Requirements – not necessarily connected to mission or physical reality**
  - **Integrated wargames, flight simulators, and physics-based modeling support early insertion of physical reality into operational assessments and cost/risk projections**
  - **Resilient system designs for flexibility to meet changing missions**

A Final Thought from Winnie-the-Pooh

It is, as far as he knows,
the only way of coming downstairs,
but sometimes he feels
there really is another way,
if only
he could stop
bumping for a moment
and think of it.